

Monitoring the 2022 Hunga Tonga-Hunga Ha'apai Aerosol Cloud Using Space-Based Observations

Ghassan Taha^{1,2}, Robert Loughman³, Peter Colarco², Glen Jaross², Tong Zhu⁴, and Larry Thomason⁵

¹Morgan State University, Baltimore, MD, USA 21251

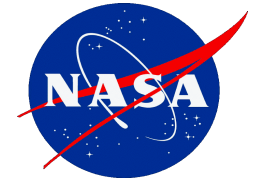
²NASA Goddard Space Flight Center, Greenbelt, MD 20771

³Hampton University, Hampton, USA

⁴Science Systems and Applications, Inc., Lanham, MD USA

⁵NASA Langley Research Center, Hampton, USA

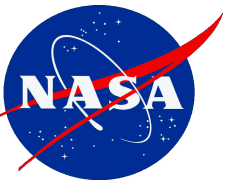




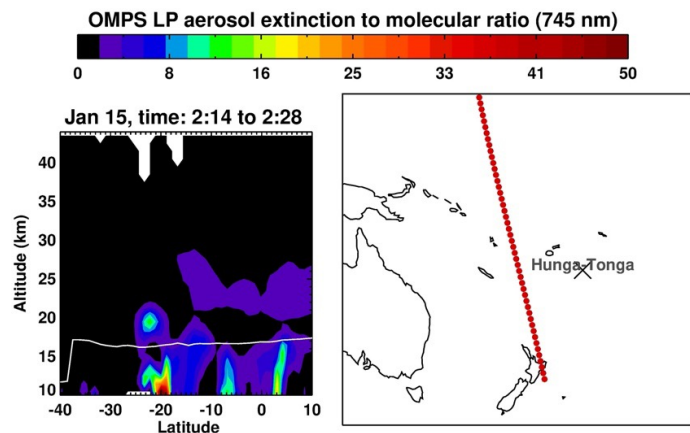
Introduction

- We will analyze the volcanic plume progression, spread and properties using space-based observations
 - OMPS LP, SAGE III/ISS, CALIPSO, TROPOMI
 - OMPS LP and SAGE III/ISS are limb instruments that measure the aerosol vertical profiles globally, while CALIPSO is a LIDAR that measures the backscatter and depolarization ratio of the aerosol profiles.
 - TROPOMI is a UV instrument that measures SO₂ and absorbing aerosol total column
 - Volcanic plume in the upper stratosphere
 - The main plume in the middle stratosphere
 - Volcanic aerosol transport to SH/NH
 - Volcanic aerosol optical properties

Updated results from Taha, G., R. Loughman, P. Colarco, T. Zhu, L. Thomason, G. Jaross, (2022), Tracking the 2022 Hunga Tonga-Hunga Ha'apai aerosol cloud in the upper and middle stratosphere using space-based observations. Geophysical Research Letters, 49, e2022GL100091. <https://doi.org/10.1029/2022GL100091>.

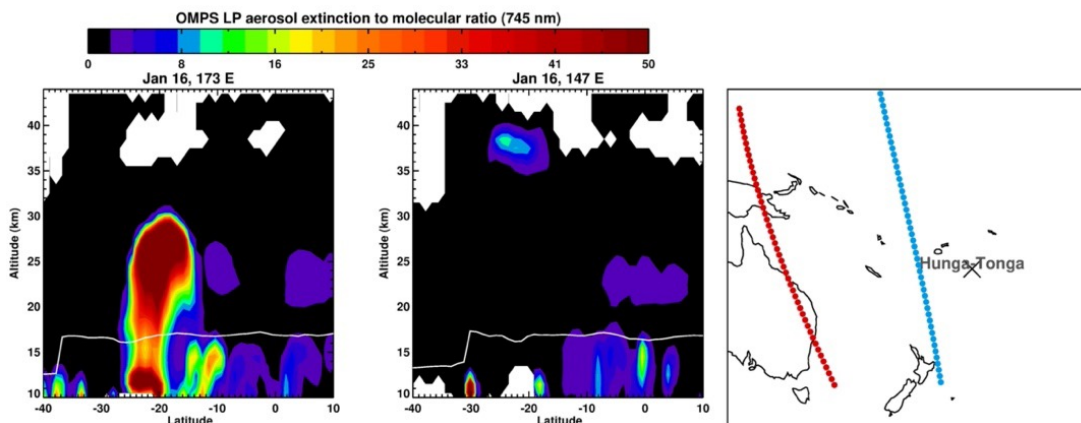


Volcanic eruptions on Jan 13 and 15 2022

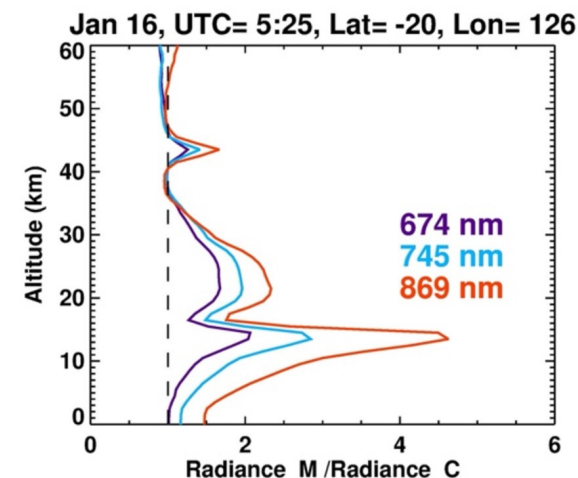
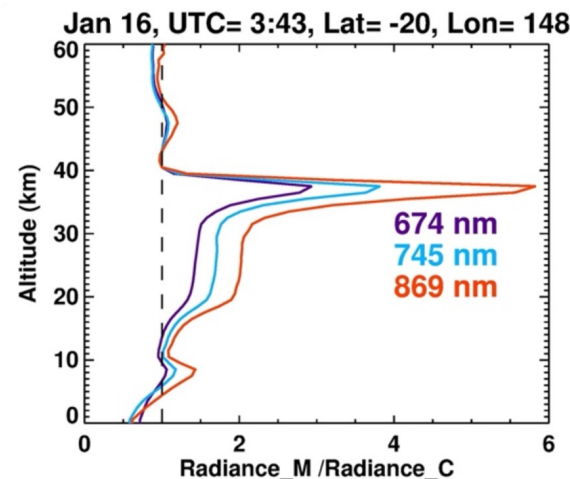


OMPS LP aerosol extinction to molecular ratio profiles measured on 15 January 2022.

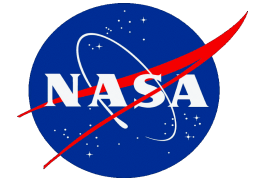
- OMPS LP observed the first eruption on Jan 15 between 18-20 km altitude
- OMPS LP observed the second and main plume on Jan 16 between 22-30 km
- OMPS also saw the plume at 46 & 50km



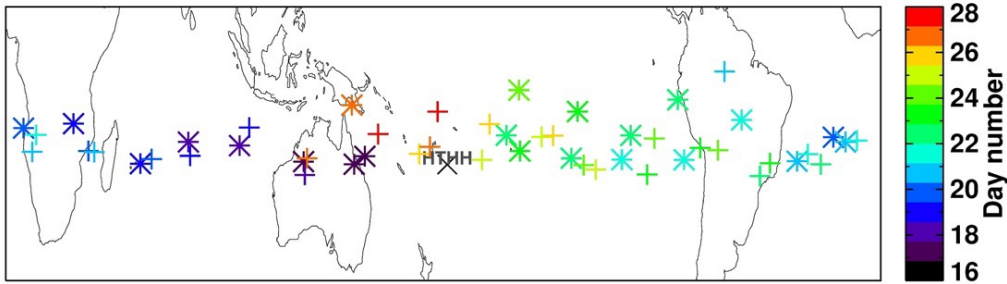
Aerosol extinction to molecular ratio profiles measured on 16 January 2022



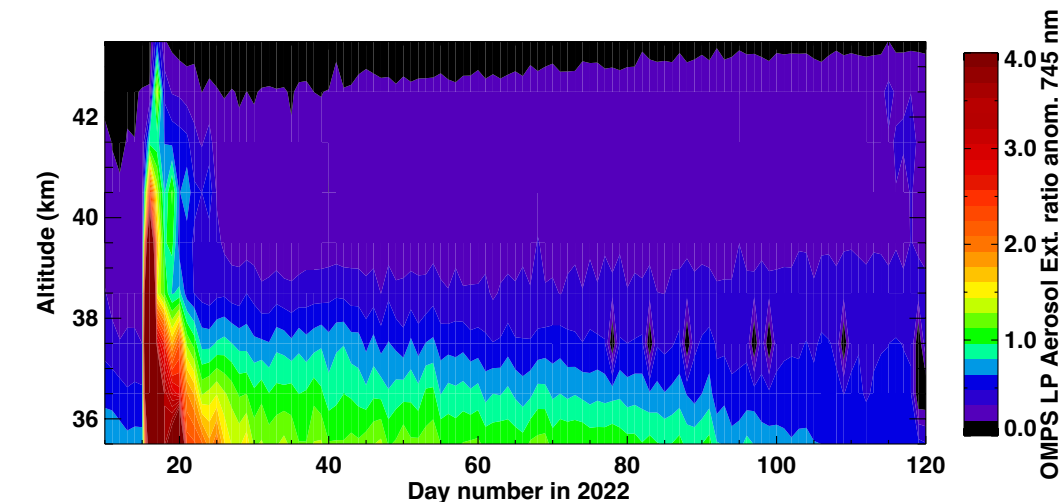
Plot of the measured to calculated radiance ratio (assuming aerosol-free atmosphere) profile for three wavelengths measured for two profiles taken on the same day



OMPS LP observations above 36 km

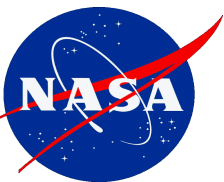


Locations of OMPS LP measurements with elevated aerosol values above 36.5 km during the first two weeks colored by the day number. Asterisk is for layers above 40 km, and plus is for layers below 40 km.

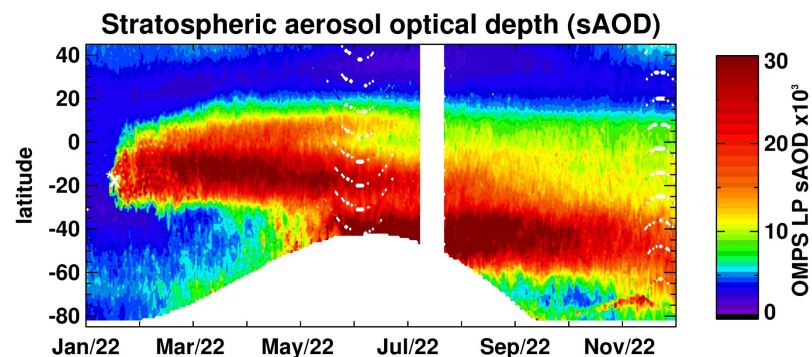


Time series of the aerosol extinction to molecular ratio (745 nm) zonal mean anomalies (25°S to 0°S) for the first four months of 2022

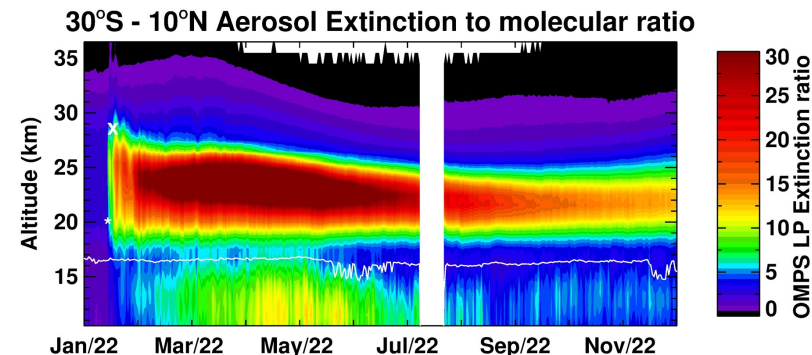
- OMPS LP tracked the aerosol cloud in the upper stratosphere for months when most instruments lost track within 2-3 days
- In one week, the plume above 40 km circumnavigated the globe and remained detectable for two weeks.
 - It took the layer at 36.5 km 10 days to circulate the world
- The aerosol layer above ~36 km remained elevated above the background levels through March
- Rapid descent of the aerosol plume during the first few days and a slower rate later



OMPS LP observations of the main volcanic plume



Stratospheric optical depth (sAOD) zonal mean at 869 nm for 2022



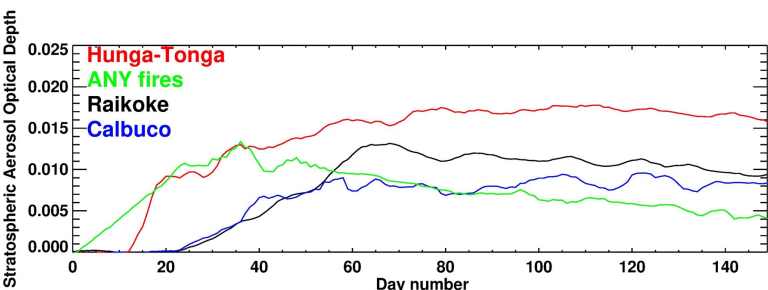
Extinction to molecular ratio zonal mean profiles between 30°S and 10°N for the same period

The plume was mainly confined in the tropics for the first few months. In May, significant parts of the aerosol layer were transported to the south pole and played a significant role in this year's large ozone hole.

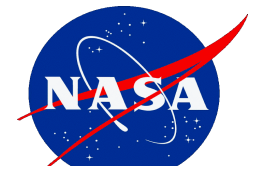
The main volcanic layer was between 20 and 26 km altitudes and exhibited a rapid descent of the aerosol layer during the first few weeks and a second slower descent in April.

-The drop in the aerosol loading after May is caused by the transport of the aerosol plume to the SH.

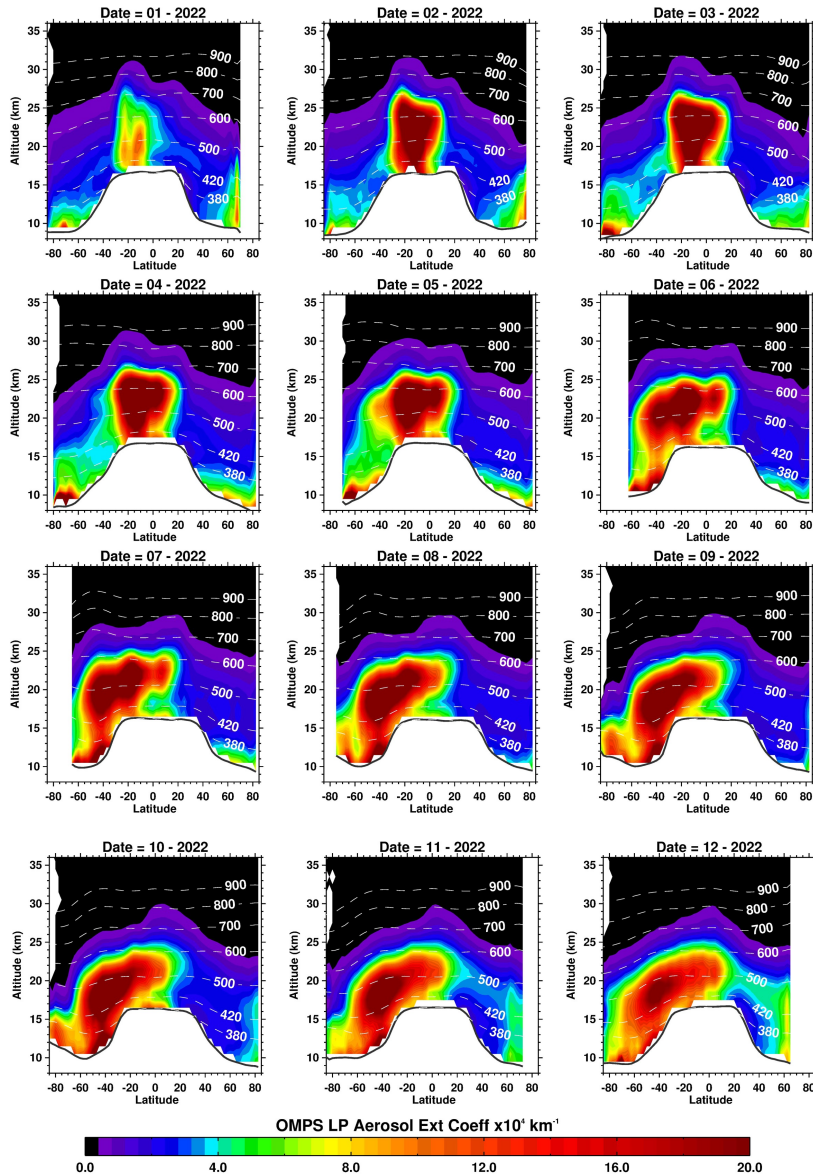
This eruption produced the highest levels of sAOD detected by OMPS LP over the last 10 years, which makes it the largest volcanic eruption since the 1991 eruption of Mt. Pinatubo



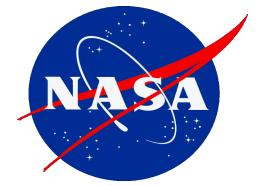
OMPS LP total sAOD Hunga-Tunga (2022), ANY fires (2020), Raikoke (2019), and Calbuco (2015) for the first 150 days.



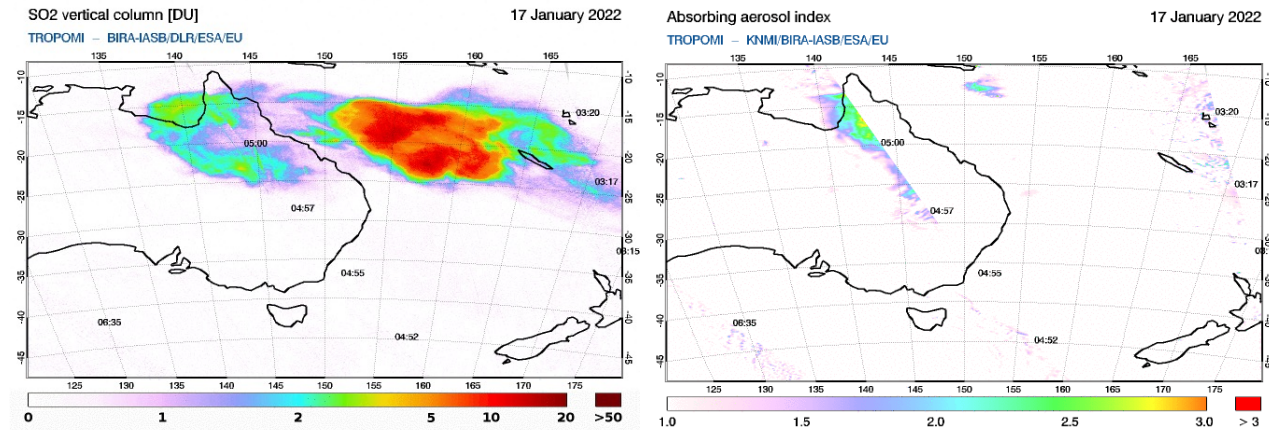
Volcanic plume evolution and transport



- OMPS LP monthly zonal mean plots
- Background conditions show elevated aerosol levels in the SH & NH lower altitudes from Le Soufriere (January)
- Poleward and downward transport of the aerosol plume toward the SH (February and later)
- Transports of the bulk of the aerosol layer to the South pole following the change of the BDC (May and later)
- Aerosol cloud moved inside the vortex at altitudes below 15 km (August to October)
 - Played a major role in the large size of this year's ozone hole
- Transport of the aerosol toward the NH (November & December)
 - Was also measured briefly in April (Taha et al., 2022)

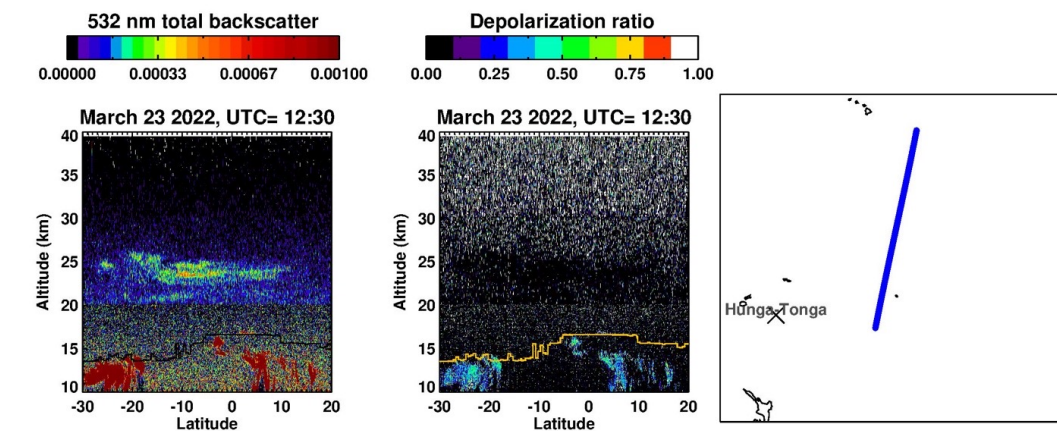


TROPOMI and CALIPSO measurements about the particle type and size



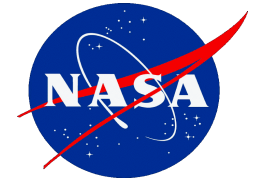
- UV measurements indicate a volcanic cloud that is rich in SO_2 and poor in ash contents.

TROPOMI UV SO_2 (left) and Aerosol Index (right) observed for January 17, 2022.

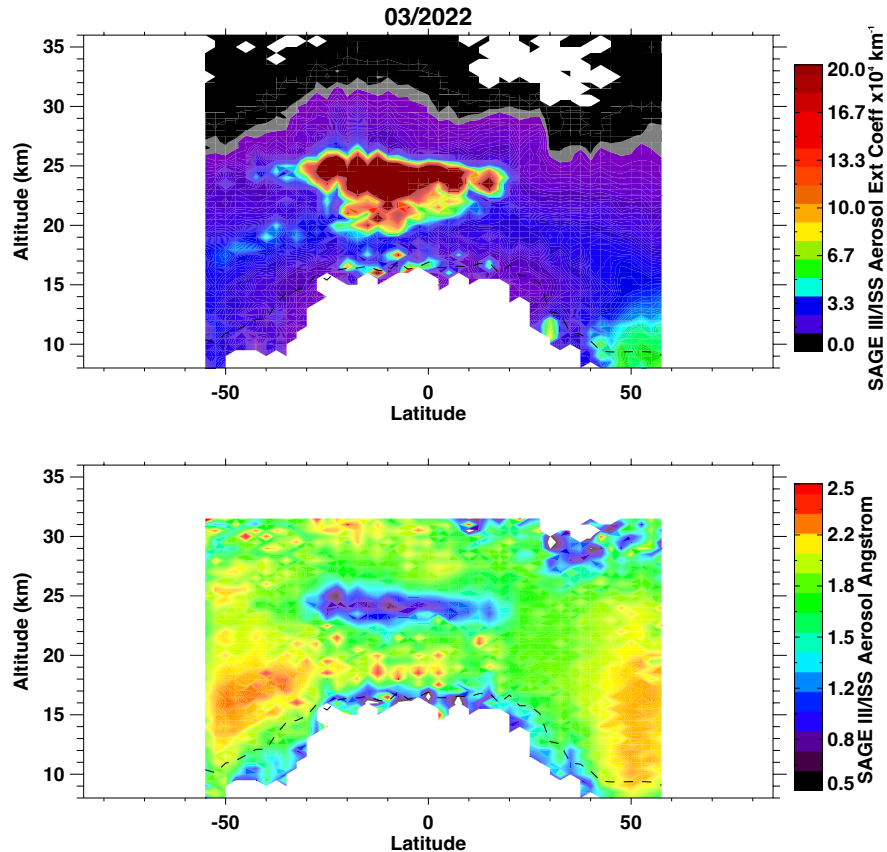


- CALIPSO near zero depolarization ratio measurements on March 23 indicate spherical sulfate particles
 - Similar ratio measured consistently throughout this eruption

CALIPSO backscatter measurement on March 23, 2022 (left) and depolarization ratio (middle)

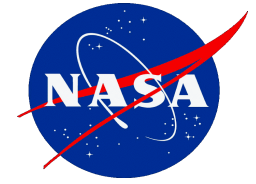


Volcanic aerosol optical properties using SAGE III/ISS



SAGE III/ISS aerosol extinction monthly zonal mean at 1022 nm for March 2022 (top). SAGE III/ISS monthly zonal mean Angstrom exponent for the same month (bottom).

- SAGE III aerosol distribution is similar to OMPS LP
 - Main layer between 20 -26 km, some transport to the SH
- Angstrom Exponent between 0.5 and 1.0 for the main aerosol layer 23 – 25 km → median radius of 0.21 to 0.28 μm
- Larger AE of 2-2.4 below the peak of the aerosol layer between 20 – 22 km and for the aerosol that is transported to the SH → median radius of 0.08 to 0.1 μm
- The larger particle size and low depolarization ratio (CALIPSO) indicate coagulation of the sulfate aerosol particulate and condensation on pre-existing aerosols
- The smaller particle size in the SH was caused by the separation of parts of the SO_2 from the water-rich main plume at higher altitudes, which resulted in the formation of the smaller sulfate particles



For more details

Taha, G., Loughman, R., Colarco, P. R., Zhu, T., Thomason, L. W., & Jaross, G. (2022). Tracking the 2022 Hunga Tonga-Hunga Ha'apai aerosol cloud in the upper and middle stratosphere using space-based observations. *Geophysical Research Letters*, **49**, e2022GL100091.
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